CHAPTER 3

DECONTAMINATION METHODS

3-1. Definition and application

Decontamination can simply be defined as the removal of radioactive material from where it is not wanted. A decommissioning program implemented immediately includes decontamination as the major effort. Numerous technologies exist, and the list of books, manuals, reports and similar documents addressing this topic is extensive. This section contains a brief description of the more common decontamination technologies and guidelines on typical application techniques. Additional information on decontamination technologies can be obtained from NUREG/CR-1915 (PNL-3706); NUREG/CR-2884 (PNL-4343); EPRI NP-2866; BNWL-B-90; EFRI NP-3508 and DOE/EV/1028-11RLO/SFM-80-3. Through an understanding of decontamination techniques, the designer can better incorporate features in the design of the facility to enhance decommissioning at a later date. Decontamination efforts can be directed toward the removal of surface contaminations accumulated due to entrapment of radioactive particulate in corrosion layers, in film deposits, or in surface crevices. Decontamination efforts can also be undertaken to remove subsurface or deep contamination resulting from activation of structural and mechanical materials or migration of deposited radioactive particulate into absorptive materials. Although decontamination techniques can be grouped into several discrete categories, two generic classifications are used for this manual; these are chemical and mechanical decontamination processes.

a. Surface Contamination. Examples of this type of contamination include the following:

(1) The buildup of corrosion products and films on the inside surface of piping or ducting in fluid systems which can entrap radioactive particles.

(2) The deposition of airborne contaminants on walls, floors, and components during the operating life of the facility.

(3) Deposition of radioactive contaminants on surfaces contacted by spilled radioactive fluids.

b. Deep Contamination. This can result from material activation due to exposure and from absorption of radioactive material. Examples are as follows:

(1) Neutrons are particularly effective in causing material activation which can occur deep into exposed material.

(2) Water with dissolved radionuclide, can be absorbed and diffused into concrete.

(3) Tritium gas will migrate into materials and can contaminate deep within that material. This deep contamination can migrate out to surfaces at later times.

3-2. Chemical decontamination

Chemical decontamination alternatives addressed here are high-concentration processes, low-concentration processes, foam cleaning, and electrochemical cleaning. Chemical decontamination is used to remove radioactive particulate entrapped on surfaces. These methods are particularly suited for decontamination of piping systems. The liquid decontamination material can be delivered through contaminated piping to remove contaminated deposits. It is useful to perform such decontamination before removal of piping systems during decommissioning. This will reduce worker exposure during removal operations. The effectiveness of chemical decontamination processes can be expressed in terms of a decontamination factor, DF, which is higher for more corrosive, reactive methods. In the selection of a chemical decontamination alternative, consideration should be given to those processes which will not create mixed waste products regulated by both NRC and Resource Conservation and Recovery Act, or similar local, state, or national hazardous waste regulatory programs.

a. High-Concentration Chemical Decontamination. These processes involve the use of chemical solutions with greater than 0.2 percent by weight of reagent. These processes have a high DF but are corrosive to the base metal, expensive, and difficult to use. In support of a decommissioning program, the corrosiveness of this decontamination process should not be a concern as long as the material is going to be discarded or the materials of construction will not fail during the decontamination process, resulting in a release of the solution.

(1) Many of these high-concentration processes are two-step processes such as AP-Citrox. The first phase is alkaline permanganate (AP), and the second phase is citric oxalic acid. These two-step processes are typically used when the radioactive contaminated corrosion film was formed in a reduced chemical environment (very low concentration free oxygen). The first phase oxidizes the corrosion film while removing very little of the radioactive material. The second phase removes most of the corrosion film and radioactive material.

(2) High-concentration decontamination processes typically produce large quantities of liquid waste which must be solidified and disposed of as LLW. This is because the concentration of dissolved solids in these solutions is very high. For example, with the AP-Citrox process, the AP phase is a 13 percent by weight solution and the Citrox phase is a 74 percent by weight solution. It is estimated that the solidified volume of LLW generated by this process is *1.5* times the volume decontaminated.

(3) High-concentration decontamination processes can remove significant quantities of radioactive corrosion films, but reduction of radioactivity concentrations to levels to allow unrestricted release of the decontaminated materials cannot be assured.

b. Dilute or Low-Concentration Chemical Decontamination. These processes include chemical solutions with less than 0.2 percent by weight reagent. These processes are less corrosive to the base metal and less costly to use than the high-concentration decontamination processes but their DFs are lower.

(1) Typically, dilute chemical decontamination techniques are one-step processes. Such processes are used when reduced personnel exposure is desired but near-total elimination of the radiation field from the radioactive corrosion film is not required.

(2) Because the concentration of chemicals in this process is dilute, waste cleanup can be achieved by recirculating the solution through ion-exchanges, thus eliminating the need for decontamination waste storage tanks required for high-concentration decontamination processes.

(3) Assuming ion-exchange cleanup of the dilute decontamination solutions, the residual, solid LLW can be estimated as one-tenth of the volume decontaminated.

c. Foam Decontamination. This technique is discussed in the literature dating back to 1971. Little interest has been shown in this technique because it is not very effective in the decontamination of piping systems at which chemical decontamination is principally directed.

(1) Foam decontamination should be considered for use on contaminated surfaces such as walls, floors, liners and any exterior surfaces.

(2) Foam decontamination uses the same foam technology as that used in foam fire-fighting apparatus. Chemicals on the order of two to three percent by weight solution are added to the foams to provide the cleaning action. A low to moderate expanded foam, less dense than shaving cream, would be used.

(3) To reduce rinse water volumes, the foam could first be vacuumed. The residue would then be rinsed away (and collected for processing) using a water rinse.

(4) Although this process does not have a high DF, residual radiation levels on walls and similar surfaces may be brought to within acceptable levels or reduce the amount of mechanical decontamination required.

d. Electrochemical Decontamination. Electropolishing essentially reverses the electroplating process, resulting in the removal of contaminated surface material. The amount of material removed depends on the duration of application, applied voltage, and current.

(1) This can be a very aggressive process resulting in both a high DF and the removal of significant amounts of base metal. When using this process in support of a decommissioning program, concern should be given to the quantity of base metal removed if reuse of a given item is proposed.

(2) Typically this process is performed in an electropolishing cell or vessel. Therefore, the use of this process could require the removal and transfer of contaminated materials prior to their decontamination.

(3) An electrobrush process can be employed using the electropolishing technique, provided that all contaminated surfaces are accessible.

3-3. Mechanical decontamination

Mechanical decontamination techniques typically involve the removal of some thickness of the material of construction of walls, floors, and pipes. The thickness of the layer of material removed depends on the process selected, which is dictated by the depth of contamination. Mechanical decontamination techniques are numerous and varied, and by no means are all processes addressed in this manual. Also, although it is likely that one or more of these methods would be used in the decommissioning, these processes have operational disadvantages that must be properly addressed when they are used. The processes are generally time-consuming, labor-intensive, create airborne contamination, create loose debris and, for wet processes, create discharged liquid waste. Recognizing these disadvantages, the use of these methods for removing contamination from surfaces can result in cost savings by eliminating the need to dispose of entire wall or floor sections as radioactive waste. Instead, only the removed contaminated material need be disposed of, thus minimizing the volume of LLW produced.

a. Concrete Surfaces. Numerous options exist, a brief list of which is provided below:

(1) Concrete Spaller. The tip (a bit with expanding wedges) of this tool is inverted into a predrilled hole. A push rod is pushed toward the end of the bit forcing it to expand radially against the wall of the hole. As the push rod approaches the bottom of the predrilled hole, it forces the wedges of the bit away, spalling a deep crater several inches deep.

(2) Scabbler/Scarifier. This tool is composed of multiple air-operated piston heads, each of which is faced with 5-or 9-point tungsten combined bits. It is effective on walls and floors when used in conjunction with a properly filtered vacuum system. This process was extensively used at Three Mile Island-Unit 2 (TMI-2).

(3) Jackhammers and Impactors. These tools are similar in effect and drive a pick or chisel point into concrete surfaces with high-energy impacts. Jackhammers are used primarily on floors because they are heavy and hard to maneuver. Impactors are more appropriate for removing contaminated surfaces from concrete walls and ceilings.

(4) Explosives. This method can be used for surface removal with excellent control of both the amount of material removed and the extent of airborne contamination generated. The first stage of concrete surface removal by explosives is to drill holes to hold the charges. When the entire length of the surface to be

removed is drilled, explosives are inserted and back-filled with sand, if necessary, to produce the desired amount of surface removal. The holes are then sealed with mortar. Blasting mats and a water spray are used to contain the dust and flying debris accompanying the explosion.

b. Piping Surfaces. Mechanical decontamination of piping surfaces was evaluated for use at TMI-2 (EPRI NF-3508). At TMI-2 the objectives of these techniques included the removal of loose debris and the removal of corrosion film. These mechanical decontamination techniques include the following:

(1) Rotating Brush-Hone. This tool consists of a large number of small, spherical silicon carbide pieces attached to the ends of a corresponding number of radially oriented stiff nylon bristles. The resulting assembly resembles a brush and can be obtained for tubing or pipe diameters from 1/4 to 36 inches. The tool is rotated inside the pipe at 150-200 rpm, using water as a lubricant and flushing medium. The configuration of this tool permits the small, individual pieces of silicon carbide to conform to the shape of the inside surface of the pipe. The individual bristle-mounted pieces can follow local irregularities and thus remove an adherent layer from the entire inner surface of a pipe.

(2) Rotating Brushes, Cutters, and Scrapers. These tools use centrifugal force to keep them in contact with the inside surfaces of the tube or pipe during cleaning. The cutters are hinged for outward movement, while the brushes and scrapers move out or expand in slots to maintain contact with the interior surfaces during solution. These devices are powered by air, water, or electric motor. They have been used for many years in industry to clean tubing or piping ranging from 112 to 13 inches in diameter.

(3) Pigs. These devices come in two basic forms. One is a plastic-bodied, bullet-shaped object that is forced through pipe or tubing by fluid pressure. It cleans by pushing loose dirt and sludge ahead of it. It can be coated with wire bristles or silicon carbide particles that scrape and abrade more tightly held material. The second type of pig includes spoke-like groups of wire bristles, arranged in a circular pattern, fastened to a center pipe section with rubber end caps to prevent by-pass of the driving fluid. Pigs are available for cleaning pipe in sizes from 112 to 60 inches in diameter. Pigs have been used extensively in non-nuclear applications.

c. Other Mechanical Decontamination Techniques. These include the following:

(1) Abrasive Blasting. In this process (applicable to metal and concrete surfaces), an abrasive material such as sand, glass beads or magnetite grit is propelled against the contaminated surface at a high velocity to remove contaminants and some of the substrate. By varying the size and conditions of the application, the surface can be scoured, polished, or peened. This process can be used with either a wet or dry application. There is no single technique or abrasive material that is universally applicable. The construction material, type of contamination, extent of decontamination desired, and complexity of the surface must all be considered.

(2) Hydrolaser. This process uses very high pressure (400 to 14,000 psi) water or steam to remove loose scale or crud. This method generates a large amount of liquid waste, but it may be possible to recycle the water since no chemicals are used. The distance between the spray nozzle and surface is important to the effectiveness of this process.

(3) Strippable Coatings. With this process a plastic membrane or coating (such as polyethylene, or polyvinylchloride) is put on the contaminated surface. This coating material is best applied with a brush. When the coating is peeled off, loose surface contaminants are removed with the coating. Strippable coatings are also often used to prevent the recontamination of decontaminated surfaces. This process has been extensively used in the nuclear industry.

3-4. Selection of decontamination process in support of a decommissioning

Each decommissioning situation must be evaluated relative to its specific conditions which influence selection of the type of decontamination processes to be adopted. Factors which affect this decision are presented below.

a. Contamination. The type of contamination that must be removed may include loose surface contamination, tough adherent film, and in- depth contamination.

b. Base Material. The contaminated material may include metal base material (vessel, pipe, liner), concrete or other material from which a surface layer could be removed.

c. Post Decommissioned Use of the Facility. The selected approach to decontamination may be different if there is no intended follow-on use of the facility (it will be totally demolished) as opposed to methods selected if the facility will be retained, refurbished, and reused.

d. Decontamination Objectives. Decontamination objectives can include the following:

(1) Reduce the radiation exposure to decommissioning personnel.

(2) Reduce the volume of low-level radwaste.

(3) Ensure that residual radioactivity levels are low enough to permit the property to be released for unrestricted use.

(4) Avoid creating a mixed waste (both hazardous and radioactive) through the proper choice of decontamination reagents.

e. Hazards Analysis and Site Safety Plan. Planning of the decommissioning process must include an activity hazards analysis and a site safety plan which shall address (but not be limited to) such factors as:

(1) Monitoring of radiation levels.

(2) Procedures to control exposures.

(3) Protective equipment.

(4) Medical surveillance.

(5) Heat stress.

(6) Staging of radioactive material.

(7) Decontamination

f. Cost Considerations. Evaluation of various decontamination choices is site specific and must be addressed on a case-by-case basis. The conditions specific to each case will determine the merits of implementing a decontamination program. Whether the objective is to reduce the personnel exposure associated with the decommissioning effort or to reduce the volume of waste, a cost-benefit analysis considering ALARA objectives should be performed. This analysis should address at a minimum the following items. (It should be noted that this is a generic list and that not every item listed is applicable to all decontamination processes).

(1) The decrease in radiation exposure to all decommissioning personnel.

(2) The personnel radiation exposure to individuals performing the decontamination.

(3) The impact of the decontamination program on the general public, which includes exposure levels related to the quantity of waste shipments and exposure due to particulate airborne and processed decontamination liquid releases. In addition, all decontamination methods described have the potential to be considered as Resource Conservation Recovery Act (RCRA) regulated wastes either because of corrosivity or the presence of dissolved metals.

(4) The cost to perform the decontamination, which includes:

(a) Process development. This includes, for example, development of the most effective chemical formulation and its application; evaluations to determine the most effective sources among several similar processes; and determination of support requirements such as flush water, electrical requirements, etc.

(b) Decontamination chemicals or equipment.

(c) Support equipment such as tanks, pumps, piping, and heat exchangers.

(d) Personnel requirements for the operation, including health physics support, engineering, and labor support.

(e) Processing of the decontamination waste which could include decanting equipment, filters, ion exchange material, volume reduction equipment, and solidification equipment.

(f) Process monitoring equipment for both the decontamination process and low-level waste processing.

(g) Interface requirements, demineralized water, power, steam, etc.

(h) Waste packaging, including containers and the labor involved.

(i) Installation and removal of process equipment.

(j) Management/supervision of the decontamination program.

(5) The impact on waste disposal costs; this would include increase or decrease costs associated with transportation, shipping cask rental and disposal fees, including appropriate surcharges and taxes.

(6) The cost reduction resulting from any salvage value gained through decontamination.

(7) A potentially significant positive cost factor would be the reclamation of a facility through decontamination. The replacement cost of the facility as it exists following decontamination should be included as a value gained and should be used to offset the cost of the decontamination.

g. General Considerations. General information on the implementation of decontamination processes in support of a decommissioning program is provided below:

(1) Radiation contamination imposed by activation represents a particularly difficult decommissioning issue. The contamination is a result of nuclear changes in the structural material due to radiation exposure during the operating lifetime of the facility. It can occur deep within structural material itself and is unlike a surface contamination resulting from entrapment of settled radioactive particles by corrosion, films, or absorption and attachment to porous surfaces. Typically, activated contamination cannot be successfully handled by decontamination. Demolition and removal is most often required. For instance, the outer layer of concrete slabs can be removed via mechanical decontamination to a depth where activation levels are lower than established limits for residual activity. This depth must be determined with certainty, which may be difficult. In addition, reinforcement steel is particularly susceptible to activation. Removal of concrete, rebar, or both could render the slab inadequate as a structural, load bearing member. When all considerations are made, it is likely that demolition and removal is required.

(2) An object of any decommissioning plan, which must be weighed against other factors, is to minimize LLW production. The volume of LLW is the important factor to consider (not weight). The removal and mechanical shredding of thin wall pipes, tanks and other components contaminated at low levels will result in a compact volume of disposable material. This option must be weighed against various decontamination options, related costs, the production of LLW through decontamination, and the salvage or reuse value of the system under consideration.

(3) Remove any buried pipes that are in need of decontamination to assure potential sources of contamination are removed and to comply with NRC criteria for release for unrestricted use.